Reply to referee 1:

Referee Comments: The authors have responded comprehensively to my comments and have adequately addressed all my questions. I have no further major comments or concerns. These are some minor comments.

Referee minor comments:

Referee minor comment 1: Figure 13 does not appear to be referred to in the manuscript. Please ensure that it is cited in the text.

Authors' Response: Good point. Figure 13 is now referenced in the paper at line 567: "Using the significant but weak empirical relationships established above, we next demonstrate aerosol vertical-profile prediction using these variables in place of vertical lidar measurements, as shown in Figure 13."

Referee minor comment 2: Please make the supplementary figure numbering style consistent throughout the manuscript, for example, use either Figure S.1 or Figure S1 consistently.

Authors' Response: Done.

Referee minor comment 3: Figures S.3 and S.4 are not directly referred to in the manuscript. Please cite them in the relevant sections or consider removing them if they are not necessary.

Authors' Response: We added reference for Figure S.3 and S.4 to help with adding meteorological background to the case studies.

Line 313 adds: Around 18:00 UTC, surface winds shifted from southwesterly to easterly, accompanied by a sudden increase in RH (Figure S.3), marking a change in near-surface air-mass influence.

Line 422 adds: Easterly to southeasterly surface winds at AMF-1 (Figure S.4a) during this period is consistent with the increasing maritime influence.

Referee minor comment 4: Please also make the in-text citation style consistent. For example, Figure S.8 is used in Line 413, whereas Fig. S.8 is used in Line 417.

Authors' Response: Done.

Referee minor comment 5. For Figure S.8, please specify the height/altitude at which these results are shown.

Authors' Response: Below is the updated Figure S.8

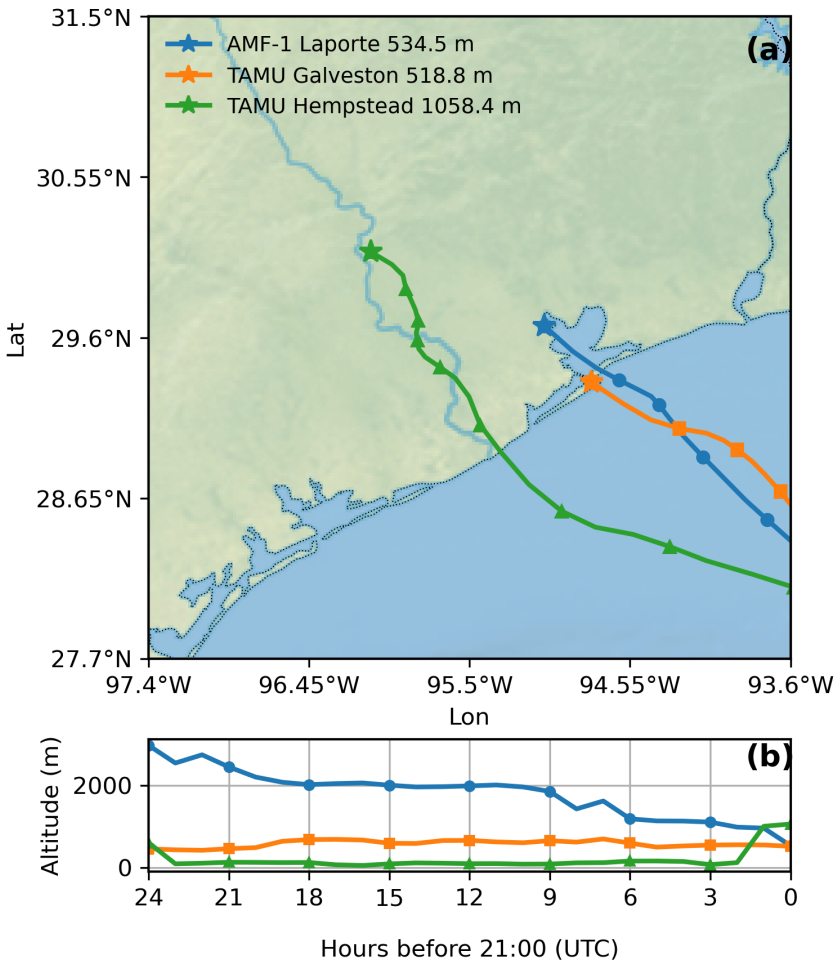


Figure S.8 HYSPLIT back trajectory evaluated for 21:00 on 8 August 2022, driven by HRRR meteorological fields (Stein et al., 2015). The arrival heights use 50% of the modeled mixed-layer depth at each site.

Reply to referee 2:

Referee overall Comment: Overall, this is a strong and well-executed study with clear novelty and substantial work. The analysis is comprehensive, and the results provide useful insights into the factors controlling aerosol vertical profiles and their relationship with boundary-layer structure. I find the study interesting and well supported by the observations. I have only a few minor comments that should be relatively straightforward to address. Overall, I recommend publication after minor revision.

Authors' Response: We thank the referee for taking the time to carefully review our manuscript and for recognizing the contributions of our study. We also appreciate referee's encouraging words and helpful suggestions.

Referee major comments:

Referee major comment 1: Page 3: The logic of the paragraphs 2 to 4 of Introduction could be strengthened to more clearly motivate the scientific questions addressed in this study. In particular, I suggest adding some limitations of existing aerosol vertical profile assumptions or parameterizations in the third paragraph to better motivate the need for the fitting functions/parameterization developed in this study.

Authors' Response: We agree with the referee that the Introduction does not adequately discuss existing aerosol vertical profile parameterizations, since developing a new parameterization is a major contribution of this study

We have added a new fourth paragraph to the Introduction, beginning at line 79: Simplified representations of aerosol vertical distributions have been used to support remote sensing retrievals of aerosol and trace-gas properties (Wu et al., 2017; Nelson and O'dell, 2019) and to estimate surface aerosol extinction from column observations (Su et al., 2017; He et al., 2016). Similar representations have also been used to prescribe and parameterize aerosol distributions in numerical models for radiative transfer calculations (Ruiz-Arias et al., 2014) and simulations of

atmospheric chemistry and cloud processes (Zhao et al., 2021; Stevens et al., 2017). These representations use Gaussian function (Wu et al., 2017; Nelson and O'dell, 2019), exponentially decreasing profile (Ruiz-Arias et al., 2014; Zhao et al., 2021), beta-function (Stevens et al., 2017) and piece-wise profile shape with uniform distribution within the boundary layer (Zhao et al., 2021; He et al., 2016). However, the complexity and variability of aerosol vertical structure can be difficult to capture with simple aerosol profile parameterization (Reid et al., 2017). For example, profiles examined in this study combine a steep near-surface decrease, a relative uniform layer above, and a sharp transition to cleaner air aloft (Figure 2c). This vertical structure is difficult to represent with a single exponential or Gaussian function.

Referee major comment 2: Page 5, Line 130: The authors note that aerosol size distributions can vary vertically in Houston, while the retrieval assumes that the surface size distribution is representative aloft. It would be important to discuss how this assumption may affect the retrieved vertical profiles and, consequently, the conclusions regarding the dependence of aerosol profiles on BLH and stability.

Authors' Response: We thank the referee for suggesting that we clarify the implications of this assumption for our results.

We have added a new paragraph at the end of section 3.6, beginning at line 596: Our analysis uses a single retrieved aerosol number concentration profile based on the assumption that the surface aerosol is representative aloft, although particles of different sizes and composition may have different vertical distributions. Tethered balloon measurements during TRACER showed variability in aerosol sizes and composition with height, although they were not co-located with our lidar observations (Mei et al., 2026). Differences in physicochemical properties do affect the conversion from lidar backscatter to number concentration and, consequently, affect the fitted profile shape and its relationship with BLH and atmospheric stability. However, the available measurements for this study do not allow us to determine how accounting for these vertical variations would change our result.

Referee major comment 3: Page 10: Could the authors clarify how aerosol and cloud signals were distinguished in the lidar observations? What criteria were used to identify and exclude cloud-contaminated regions in the NRB and depolarization ratio profiles before deriving the aerosol vertical distributions.

Authors' Response: Clouds were identified using an algorithm which combines a continuous wavelet transform with threshold criteria to detect cloud related peaks in the normalized relative backscatter (NRB) profiles. According to our previous work, Chen et al., 2025), cloud-contaminated periods were excluded before time averaging the remaining cloud-free profiles and performing the aerosol backscatter inversion.

For examples of cloud masks produced by this method see Chen et al, Supplement (2025).

Referee major comment 4: Page 24: The uncertainty in the prediction may propagate through the different steps, because r_m is estimated from BLH and k is then estimated using the temperature gradient around r_m. The authors may briefly discuss how these uncertainties could affect the final predicted aerosol profiles.

Authors' Response: This is a good point. Discussion of impact of the uncertainty on aerosol profiles is now
Pg 24 line 591 now reads:

Uncertainty in the estimated r_m also affects the altitude range used to determine the temperature gradient and therefore the estimated k. These linked uncertainties may affect both the location and sharpness of the transition in the predicted aerosol profile. Thus, an accurate r_m is crucial for an accurate estimate of k.

Referee minor comments:

Referee minor comment 1: Page 18, Line 400: For descriptions of the vertical profiles (e.g., Figure 10), could the authors include the corresponding time and figure number after phrases

such as “the early afternoon”? These details are provided for some descriptions but not consistently throughout the text.

Authors’ Response: We thank the referee for this suggestion. We have added the corresponding time and figure reference to the profile descriptions in Sections 3.1–3.3 to make the text easier to follow.

Referee minor comment 2: Page 11, Figure 5: The fitted transition height r_m is important to the discussion and is compared with BLH-RiB, it may be helpful to indicate r_m directly in Figure 5 and other vertical profile figures.

Authors’ Response: We have updated the figures with fitted r_m indicated in the figures. Below are the updated figures.

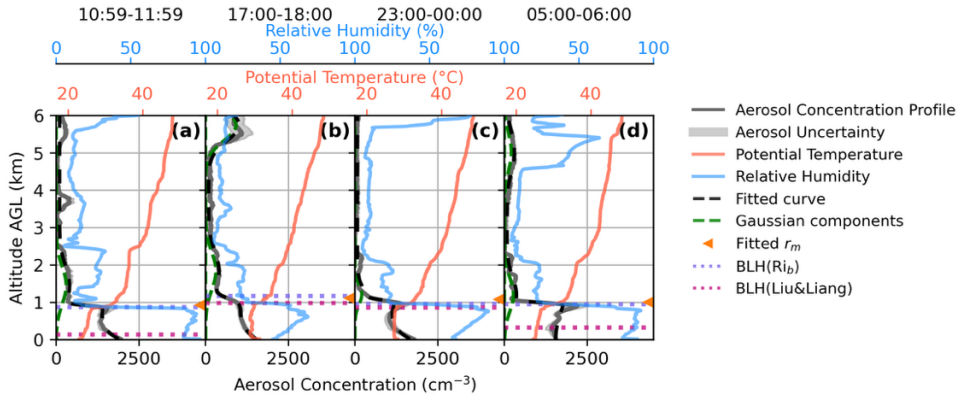


Figure 1 Retrieved vertical profiles of aerosol number concentration (gray solid lines), potential temperature profiles (solid red lines), relative humidity profile (solid blue lines), and curve fit aerosol vertical profile (dashed black lines) at the AMF-1 site on 18–19 May 2022. Green dashed lines indicate Gaussian components added to represent elevated aerosol layers. Orange triangles mark the fitted transition height r_m. BLHs determined by the bulk Richardson number and the Liu & Liang method are shown as purple and magenta dotted horizontal lines, respectively. The curve fit profile closely overlaps the measured number-concentration profiles, so the gray lines can be difficult to distinguish from the black dashed lines where agreement is good. Each panel corresponds to a one-hour averaging window in UTC time: (a) 10:59–11:59 on 18 May, panel (b) 17:00–18:00 on 18 May, (c) 23:00–00:00 across 18–19 May, and (d) 05:00–06:00 on 19 May.

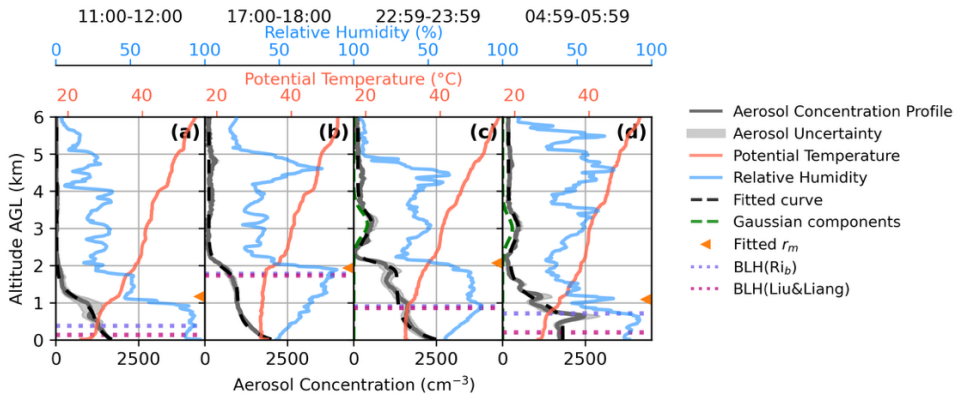


Figure 2 Measured vertical profiles of aerosol number concentration (gray solid lines), potential temperature profiles (solid red lines), relative humidity profile (solid blue lines), and curve fitted aerosol vertical profile (dashed black lines) at the AMF-1 site on 21–22 July 2022. Green dashed lines indicate Gaussian components added to represent elevated aerosol layers. Orange triangles mark the fitted transition height r_m. Boundary layer heights determined by the bulk Richardson number and the Liu & Liang method are shown as purple and magenta dotted horizontal lines, respectively. The curve fit profile closely overlaps the measured number-concentration profiles, so the gray lines can be difficult to distinguish from the black dashed lines where agreement is good. Each panel corresponds to a one-hour averaging window in UTC time: (a) 11:00–12:00 on 21 July, panel (b) 17:00–18:00 on 21 July, (c) 22:59–23:59 on 21 July, and (d) 4:59–05:59 on 22 July.

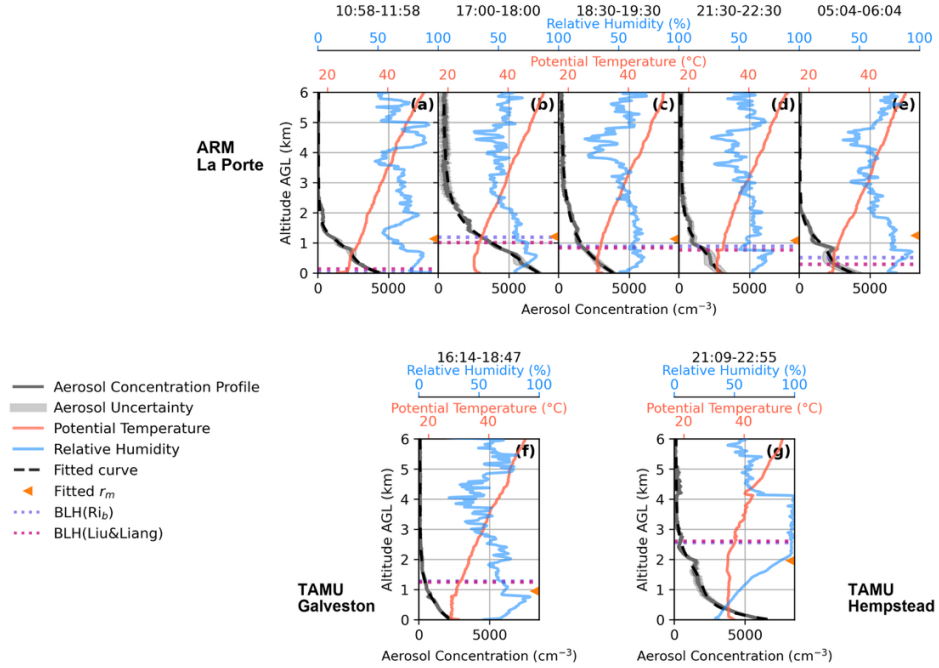


Figure 10 Measured vertical profiles of aerosol number concentration (gray solid lines), potential temperature profiles (solid red lines), relative humidity profile (solid blue lines), and curve fitted aerosol vertical profile (dashed black lines) at the AMF-1 site and two TAMU sites on 8–9 August 2022. Orange triangles mark the fitted transition height r_m.

Boundary layer heights determined by the bulk Richardson number and the Liu & Liang method are shown as purple and magenta dotted horizontal lines, respectively. The curve fit profile closely overlaps the measured number-concentration profiles, so the gray lines can be difficult to distinguish from the black dashed lines where agreement is good. Each panel corresponds to a one-hour averaging window in UTC time. AMF-1 site: (a) 10:58–11:58 on 8 August, (b) 17:00–18:00 on 8 August, (c) 18:30–19:30 on 8 August, (d) 21:30–22:30 on 8 August, and (e) 05:04–06:04 on 9 August. TAMU Galveston site (f) 16:14–18:47 on 8 August. TAMU Hempstead site (g) 21:09–22:55 on 8 August.

Referee minor comment 3: Page 18, Line 395: The interpretation of the increase in near-surface aerosol concentration could be clarified. Boundary-layer development generally enhances vertical mixing and dilution, and therefore may not directly explain the observed increase in surface concentration.

Authors' Response: We have expanded the sentence to clarify the explanation.

Line 418 now reads: "At the AMF-1 site, the near-surface aerosol concentration increases from approximately 4400 cm^{-3} in the early morning (10:58–11:58 UTC; Figure 10a), to 7200 cm^{-3} around noon (17:00–18:00 UTC; Figure 10b), accompanied by higher concentration aloft. During this period, the BLH increased from below 0.2 km to approximately 1 km. Although boundary layer development may enhance mixing and dilution, local emissions or transport of aerosol rich air may have contributed to the observed increase."